POTABLE WATER CBR CONTAMINATION AND COUNTERMEASURES

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This paper provides information on the potential threat to a building's domestic and potable water supplies from chemical, biological, and radiological (CBR) agents that could potentially be used by terrorists, wartime or terrorist attacks, or accidental or intentional (sabotage) toxic industrial chemical release. The consequences of a CBR terrorist attack or industrial release are assumed to be short in duration, lasting only a few hours. However, decontaminating a distribution system may take several days for chemical and biological (CB) agents; radioactive material releases that contaminate a water distribution system, would make the distribution system unusable for months or years. This paper provides design measures that can be used to provide protection based on the threat type and severity level from a minimum through high level of protection. Emphasis will be placed on assessing potential CBR agent release tactics, identifying vulnerable locations in a water supply system where CBR agents might be released, and countermeasures to protect against a CBR threat. Water systems supplying buildings can become contaminated at any one of three stages: (1) at the source (e.g., well fields/production wells, reservoirs, lakes and rivers, or water treatment plants), (2) in distribution lines and loops (on- and off-base) feeding buildings, or (3) in a building's system of pipes, pressure tanks, holding tanks or water softener treatment system.

GENERAL

This paper provides information on the potential threat to a building's domestic and potable water supplies from CBR agents that could potentially be used by terrorists (taking into consideration they would likely use low-technologies or agents most readily available). People, both mission critical and the general population, are the most commonly targeted assets of aggressors using CBR agents. CBR agent threats can come from wartime or terrorist attacks or accidental or intentional (sabotage) industrial chemical releases. It is generally assumed that the catastrophic consequences of a CBR terrorist attack or industrial release would be short in duration, perhaps lasting only a few hours. However, decontaminating a potable water distribution system of a CB agent may take several days. Radioactive material releases can contaminate a water distribution system making it unusable for months or even years creating an enormous health impact. If a small military camp was targeted, the camp could be moved, but if a large distribution system was attacked, the problem of supplying water could be detrimental.

1. Waterborne Agents

Table 1 indicates potential types of waterborne CBR agent categories that a terrorist organization might have access to and the threat severity. The emphasis has been placed on assessment of potential CBR agent release tactics, identifying vulnerable locations in a water supply system where CBR agents might be released, and countermeasures to protect against the CBR threat. In general, to deliver an effective dose of a chemical agent or toxin or an infective dose of a biological agent, the contaminant must be introduced close to the point of consumption.

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TABLE 1. CBR Waterborne Agent Categories and Threat Severity

CBR Agents	Threat Severity
Chemical	
Military agents (7 primary)	Significant
Industrial and Agricultural toxic chemicals 60,000 listed	Wide-range
Biological (microorganisms)	
Bacterial (infectious cells and spores)	Wide-range (some very serious)
Viruses	Significant
Protozoa (cysts and oocysts)	Less likely heath threat
Biotoxins	Most serious
Radionuclides	
Radiation dispersal weapons "dirty bombs"	Very serious

a) There are many chemical agents which may do harm to a population when introduced into a water supply system even through they were not intended for such a purpose. In general, the nerve, blood, and blister agents are a significant threat to water supply systems. Biotoxins are a more serious threat, with the botulinum biotoxin being the most serious. Studies will be conducted to better understand a biotoxin survival rate in chlorinated water. All types of bacterial agents could detrimentally affect at least some portion of an exposed population. Viruses in water are also a significant threat. Fungi and protozoa are less likely to pose a hazard. Several protozoa are considered to be a threat more because of their ability to survive in water and their potential to cause illnesses rather than their potential to cause fatalities. Their low infectious dose, high resistance to disinfectants, and easy availability make them a concern as potential biological agents. The toxic industrial and agricultural chemicals pose a wide range of threats ranging from benign to highly toxic.

2. Factors Reducing Occupant Vulnerability

Building occupant vulnerability to waterborne contaminants is determined in large part by the effectiveness of: (1) dilution, (2) treatment plant filtration, (3) specific inactivation from chlorine, chloramines, ozone, or other water disinfectants, (4) nonspecific inactivation by such factors as hydrolysis, sunlight, and indigenous microbe degradation of the released agent, (5) the small quantity of treated water (1.0 to 1.5 L/day) that is actually ingested directly from the tap or in beverages prepared from un-boiled tap water, (6) point of entry into water system and water system hydraulic flow, and (7) a distribution system's external and internal security measures to prevent the introduction of an agent.

3. Exposure Routes

Contaminated water represents a hazard through ingestion (e.g., cooking, drinking, etc.), skin contact (e.g., sinks, showers, etc.), or inhalation (e.g., showers, aerosols, humidifiers, etc.). Should large numbers of people become sick at the same time with similar symptoms, water should be one of the main suspected sources. The two other main suspected sources would be contaminated/tainted food or air. Whether a person contracts a CBR disease depends on: (1) type of agent, (2) concentration and strength of the agent, (3) volume of water associated with ingestion, skin contact (including contact with mucous membranes in the mouth or eyes), or inhalation (shower aerosols), and (4) susceptibility of the individual. Biotoxins and microorganisms will probably be the primary form of contamination of drinking water.

4. Water Requirements

Because it is a vital consumable, potable water is the most significant of the utilities and contamination or loss of it (or the loss of the ability to use it) could potentially cause the greatest damage to human health and a major disruption to the lives of those dependent on it. The target minimum water quality supplied should meet water quality requirements of the Safe Drinking Water Act for permanent water systems in CONUS, and for deployed locations, the requirements of Field Manual FM 10-52 WATER SUPPLY IN THEATERS OF OPERATIONS, 11 JULY 1990 and the proposed tri-service water standards, 15L/day for long-term consumption.

Table 2 lists physical properties of certain agents and their recommended maximum ingestion concentrations.

TABLE 2. Proposed Tri-Service Water Standards

Inorganic Chemical	**Concentration Level**
Arsenic	0.02 (mg/L)
Cyanide	2 (mg/L)
Chloride	600 (mg/L)
Lindane	0.2 (mg/L)
Magnesium	30 (mg/L)
Sulfate	100 (mg/L)
Chemical Agents	
Hydrogen Cyanide	2 (mg/L)
Incapacitants (BZ)	2.3 (µg/L)*
Lewisite – Arsenic fraction (µg/L)*	27 (µg/L)*
Sulfur Mustard (µg/L)*	47 (µg/L)*
VX*	5.0 (µg/L)*
GD*	4.0 (µg/L)*
GB*	9.3 (µg/L)*
GA*	46 (µg/L)*
Biotoxins	
T-2 Toxins*	8.7 (µg/L)*
Radiological agents	
Radioactive material	0.05 (µCi/L)

5. Chemical Agent Medical Effects When Ingested in Drinking Water

Classical military chemical warfare (CW) nerve agents cause an increase in muscle contractions in the gastrointestinal (GI) tract and an increase in secretions by the glands in its walls. Pulmonary intoxicants, as gases, are extremely unlikely to be ingested.

6. Biological Agent Medical Effects

Biological and biotoxin agents can manifest themselves as a wide variety of diseases that are incapacitating or lethal. Some are fast-acting (symptoms are noticeable within minutes) while others may take a period of time, perhaps days or weeks, before symptoms become apparent.

7. Radioactive Material Caused Medical Effects

An insoluble radioactive material that is ingested will remain in the GI tract and become mixed in and part of the fecal material in the large bowel, and then eliminated. Insoluble material is not retained in the GI tract and the radiation exposure hazard is limited to the required for transit and elimination, generally a matter of hours. As a result, the radiation hazard is negligible, unless the material includes a highly active gamma emitter. Normally, beta and alpha radiation from insoluble radioactive material in the GI tract will not cause significant damage. The few cells of the lining of the GI tract that are damaged by radiation are routinely sloughed off and replaced rapidly. Highly radioactive fallout containing fission products emitting beta and gamma radiation could cause some GI tract damage if contaminated water is accidentally ingested.. When a soluble material is ingested, absorption is quite efficient. This is the most significant route of entry for the soluble isotopes in fallout, particularly when fallout-contaminated water is consumed.

8. Some Agricultural Chemical Medical Effects

Some examples of agricultural chemicals and their toxic effects are presented to provide an overview of the potential cause for concern. Ingestion of a toxic dose of 2,4-D causes GI tract distress, diarrhea, mild central nervous system depression, dysphagia, and possible liver and kidney damage. Ingestion of a toxic dose of cacodylic acid may cause slight burning of the mouth and throat, GI tract pain, vomiting, diarrhea, dehydration, jaundice, and collapse or shock.

9. Persistence of Agents

Some chemical agents hydrolyse in water within a short period of time (i.e., mustard has a half-life of 15 minutes and BZ hydrolyses as it passes through microfilters) and others have much longer half-lives (i.e., VX has a half-life of 110 to 120 hours in well water). The degree of persistence of biological agents varies widely (e.g. the half-life of *Vibrio cholerae*, *Shigella* species, *Escherichia coli*, and *Salmonella* species ranges from 7 to 16 hours, while *Bacillus anthracis* spores have a half-life of up to several years). The most dangerous fission products are: (1) thyroid-seeking iodine-131 with a physical half-life of 8 days, (2) bone-seeking strontium-90 with a physical half-life of 29 years, and (3) muscle-seeking cesium-137 with a physical half-life of 30 years, and biological half-life 70 to 140 days. Industrial toxic chemicals have variable persistence characteristics and will leave the water based on their chemical properties or by chlorine-induced attenuation.

10. Internal Building Release

Aggressors may forcibly enter a facility using a “forced entry tactic” or aggressors may gain access to a building by use of a “covert entry tactic” to release a waterborne agent inside a building’s distribution system. Buildings having accessible aboveground gardening faucets are vulnerable to direct insertions of agents into the building's water system. All faucets are vulnerable to an internal release, depending on physical accessibility and line pressure. Agents can be introduced into a building’s water distribution system if the water line pressure in its piping, pressure tanks, or water softener treatment system is overcome. A device (e.g., pressurized tank), multiple devices, or an explosive set to release a large quantity of a CBR agent can be either concealed in a building’s water supply system or placed out in the open.

11. External Release

CBR agents can be introduced at the raw water source, at water treatment buildings and storage facilities, through on- or off-base water distribution systems, or at expeditionary water points. Table 3 list potential locations for terrorist action where if agents are introduced would cause a major disruption in delivering potable water. These insertions can be directed to a building from outside the security perimeter or control points. A pumper truck, fire truck or portable high-pressure pump could overcome low-pressure distribution line pressure and introduce CBR agents into a system. A tanker truck (or another vehicle) could be driven into a source body of water releasing large quantities of an agent.

TABLE 3. Potential Locations for Terrorist Action

	Potential Location
(1)	At the source (e.g., well fields/production wells, reservoirs, lakes and rivers, and transmission through aqueducts, tunnels, pipes, etc.)
(2)	At the water treatment plant (e.g., coagulation/flocculation process, filtration beds, organic removal, disinfectant feed system, etc.)
(3)	During storage of treated water (e.g., clear well (covered facility), elevated tanks, etc.)
(4)	In on- and off-base distribution lines and loops (e.g., fire hydrants, blow-off valves, pump stations, etc.)
(5)	In a building's system of pipes, pressure tanks, holding tanks, or water softener treatment system
(6)	Through cyber attacks on supervisory control and data acquisition network (control equipment such as pumps, filters, chemical metering, flow, and pressure rates)
(7)	Through interdependent connections (e.g., treated water, chemical deliveries, electrical power, etc.)

a) If security systems are not maintained, terrorists or disgruntled former (or current) employees could introduce CBR agents into water treatment facilities or storage systems. Large quantities of chemicals used at water treatment plants could be used as agents.

b) Hackers from remote locations (even from overseas locations) can be compromise control and data acquisition networks (which control and monitor equipment such as pumps, filters, tanks, chemical feeders and interdependent connections).

12. Toxic Industrial and Agricultural Chemical Release

More than 60,000 toxic chemicals are being used by various segments of industry and agriculture. Intentional or accidental toxic industrial or bulk agricultural chemical releases from tanker trucks or rail tank cars would most likely affect water sources and treated water storage with access locations.

13. Nuclear Power Plant Disaster

The potential public health hazard from a nuclear power plant disaster is fairly minimal. As a result there is very little chance of these elements being ingested by humans via drinking water. However, an incident would involve large and uncontrolled releases of radioactive material or compounds into the environment and water supply sources. In the case of a nuclear disaster, surface water supplies could initially become contaminated within a 50 mile (80.5 km) radius of the nuclear power plant. Groundwater supplies would remain safe for a longer period of time.

14. Nuclear Weapon Detonation

In a surface burst, large amounts of earth or water will be vaporized by the heat of the fireball and drawn up into the radioactive cloud. This material will become radioactive when it condenses with fission products and other radio-contaminants or has become neutron activated. There will be large amounts of particles of less than 0.1 micrometer to several millimeters in diameter generated in a surface burst in addition to the very fine particles that contribute to fallout.

15.

Adaptation of commercially available water system modeling software package can be used to determine vulnerability of buildings and parts of bases to terrorist attack using waterborne agents. The U.S. Army Civil Engineering Research Laboratory (CERL) conducted a computer run to demonstrate the vulnerability to a CBR agent injected into a fire hydrant within 1/2 mile of a targeted building (Figure 1).

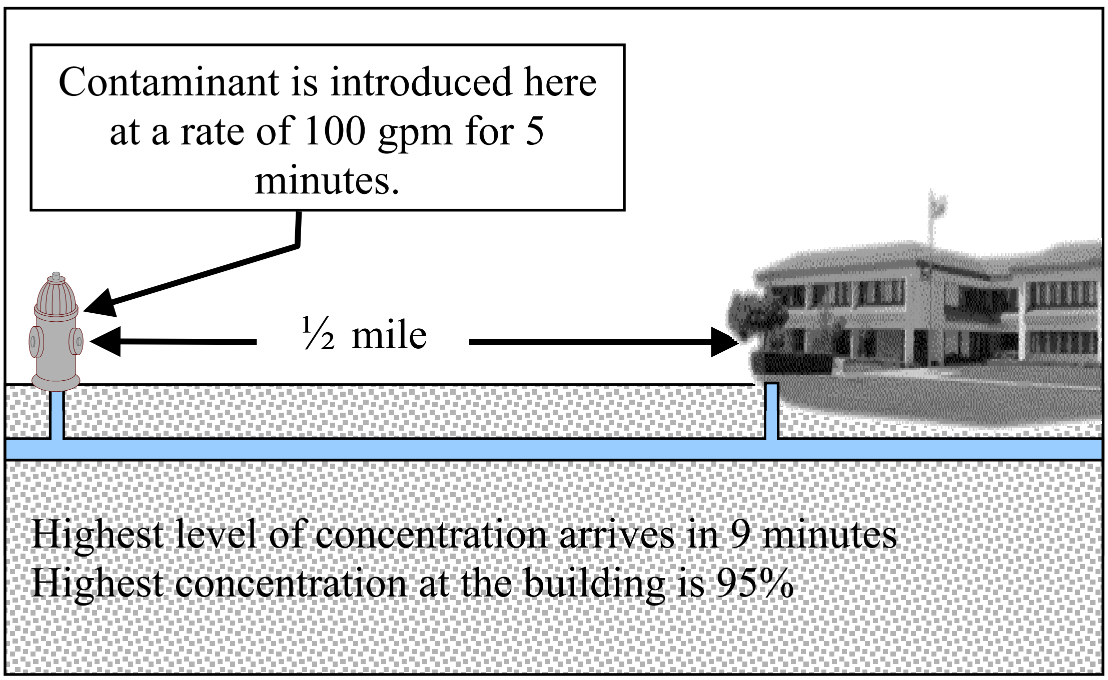

Figure1. Generalized model out put for an agent injected into a fire hydrant within a 1/2 mile of a targeted building.

16. Agent Monitoring

Various field grab sample water-testing techniques are capable of screening some chemical agents, detecting (but not quantifying accurately) radioactivity, screening for some industrial chemicals, and providing limited biological agent detection capabilities. More sophisticated and time-consuming laboratory analysis methods are required to accurately detect and quantify most threat agents and these resources may or may not be readily available to a unit commander in a timely manner.

17. Threat Severity Levels for Waterborne Contamination

In general, particulate agents will cause the greatest threat to a water supply system. Liquid agents follow particulates in threat level and vapor agents follow liquids. Vapor agents forced into water would not be considered a major threat, since the concentration of the agent could not be very substantial and it would dilute to a very low concentration while in route to the consumer. However, there may be a problem if the agent is introduced into the system at a very high concentration near the point of consumption. One way to evaluate threat severity levels is to determine how long the contaminant will stay viable in the water system. Table 4 provides general guidelines on levels of threat. These guidelines do not take into consideration the danger of highly infectious agents that could potentially be introduced near the point of consumption and have grave results.

TABLE 4. Levels of Threat

Threat Level	**Definition**
Low	Agent is not stable in water for periods greater than 2 hours
Medium	Agent is stable in water for more than 2 hours and for up to several days
High	Agent is stable in water for periods greater than 30 days (e.g., a radioactive material)

18. Countermeasures

Three primary countermeasures are available to overcome or reduce the potential introduction of CBR agents into water supplies. These countermeasures in order of priority are: (1) contamination avoidance, such as the use of protective barriers; (2) use of CBR agent detection, measurement, and identification instrumentation or methods; and (3) CBR agent treatment to minimize water distribution disruption, such as removal by filtration and disinfectant techniques. These priorities are established to reflect the greatest potential return in terms of operational effectiveness, and conservation of resources and manpower. That is, the greatest benefit by far will be achieved by using contamination avoidance techniques and procedures in advance of an expected attack and subsequent to an attack.

19. Levels of Protection

Levels of protection refer to the degree to which an asset is protected against the threat based on its value to the user. A high level of protection corresponds to a low likelihood that an asset will be compromised if attacked. A low level of protection equates to a low cost, higher likelihood of defeat or risk of exposure, and higher vulnerability of assets. The target minimum water quality supplied to inhabited buildings is the water quality requirements of U.S. Army Field Manual FM 10-52-1. Water system protection can be divided into three levels of protection (minimum, moderate, and high) and are described in Table 5. The levels of protection only address liquid and particulate threats, as vapor is not considered a viable threat. Table 5 describes specific levels of protection to mitigate the waterborne threats.

TABLE 5. Levels of Protection

Protection Level	Definition
Low	The current water treatment and delivery system
Medium	Stand-by treatment systems installed within the building and operated during periods of high threat
High	A continuous water treatment system operating for a specific building or a dedicated potable water well installed within the building

20. Water Treatment

CBR agents can generally be found in two basic physical states (1) liquid or dissolved organic chemicals and (2) particulates (i.e., infectious agents, biotoxin crystals, radiological agents, etc.). A survey of the extent of the contamination and concentration is required to determine a corrective action. No one treatment can remove all CBR threat agents. Various commercial systems are available which can be connected together in a treatment train to treat CBR-contaminated water. Two factors, (1) dilution and (2) the residual chlorine, or other disinfectant in treated water, generally make it difficult to introduce an effective dose of most CB agents into a building. There are some CBR agents that are resistant to even high concentration of chlorine and, therefore, are impervious to treatment by chlorination. Chlorine residual gradually decays before it is used due to its movement through the distribution system and its residence time, which may be between a day to a week or so. Table 6 indicates relative efficiency of agent removal by water treatment technologies. Units have also been assembled by the military that can achieve the same results.

TABLE 6. Relative Efficiency of Agent Removal by Water Treatment Technologies

	Chemical Agents	Bacteria (reproducing)	Spores	Viruses	Protozoa (reproducing)	Cysts & Oocysts	Biotoxins	Nuclear
Air Stripping, Aeration	VS	P	P	P	P	P	P	P
Coagulation Sediment/Filtration	P	G-E	G-E	G-E	G-E	G	P	G
Granular Activated Carbon	G*	F	F	F	F	F	VS*	P
Micro filtration	P	E	E	P	E	E		E**
Lime Softening	VS	G-E	NA	G-E	G-E			P
Ion Exchange	P	P	P	P	P	P	P	E
Reverse Osmosis	E	E	E	E	E	E	E	E**
Ultra Filtration	P	E	E	E	E	E		E**
Disinfection, Chlorine	VS	E		E		P	VS	P
Disinfection, Ozone	VS	E		E				P
Disinfection, UV Irradiation	NA	E		E	E			P

NOTE: P - Poor ((0 to 20% removal)
F - Fair (20 to 60% removal)
G - Good (60 to90% removal)
E - Excellent (90 to 100% removal)
VS - Vary Significantly
NA - Insufficient Data
* - Require pretreatment
** - Particles Removed

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